FORM PTO-1390 (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 712-032

U.S. APPLICATION NO (If known, see 37 CFR 1.5): 10/019852

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP00/02648	11 November 2000	19 May 1999

TITLE OF INVENTION: DLC FILM , DLC FILM-COATED PLASTIC CONTAINER, APPARATUS FOR PRODUCING IT, NAD METHOD FOR PRODUCING IT

APPLICANT(S) FOR DO/EO/US: Shigeki MORI, Yuuji YAMASHITA and Tsuyoshi KAGE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. [X] The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. [ ] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is attached hereto (required only if not communicated by the International Bureau).
   b. [ ] has been communicated by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [X] An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. [X] is attached hereto.
   b. [ ] has been previously submitted under 35 U.S.C. 154(d)(4).
7. [ ] Amendments to the claims of the International Aplication under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are attached hereto (required only if not communicated by the International Bureau).
   b. [ ] have been communicated by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [X] An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] An English lanugage translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [X] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [ ] A FIRST preliminary amendment.
14. [ ] A SECOND or SUBSEQUENT preliminary amendment.
15. [ ] A substitute specification.
16. [ ] A change of power of attorney and/or address letter.
17. [ ] A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. [ ] A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. [ ] A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. [X] Other items or information: Copy of Form PCT/IB/306 and International Search Report

U.S. APPLICATION NO (if known, see 37 CFR 1.5) 10/019852	INTERNATIONAL APPLICATION NO PCT/JP00/02648	ATTORNEY'S DOCKET NUMBER 712-032

21. [x] The following fees are submitted:	CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1000.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$860.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$710.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	13 - 20 =	0	x **$18.00**	$ 0	
Independent claims	5 - 3 =	2	x **$80.00**	$ 168.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$270.00**	$ 280.00	
TOTAL OF ABOVE CALCULATIONS =				$	
[ ] Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.			+	$	
SUBTOTAL =				$ 1,338.00	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$	
TOTAL NATIONAL FEE =				$ 1,338.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$ 40.00	
TOTAL FEES ENCLOSED =				$ 1,378.00	
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a. [X] A check in the amount of $ 1,378.00 to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. _____ in the amount of $ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 08-1540 . A duplicate copy of this sheet is enclosed.

d. [ ] Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

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25,669
REGISTRATION NUMBER

Docket No.: **712-032**

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DLC FILM, DLC FILM-COATED PLASTIC CONTAINER, APPARATUS FOR PRODUCING IT, AND METHOD FOR PRODUCING IT

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to DLC film-coated plastic containers suitable to beers, sparkling wines, wines, high-fruit drinks and others that are sensitive to oxygen.

Description of the Related Art:

In general, plastic containers are easy to form, lightweight and inexpensive, and are therefore widely used as packing containers in various fields of edibles, drinks, medicines, etc.

As well known, however, plastics have the property of passing low-molecular gases such as oxygen, carbon dioxide and others therethrough, and the property of absorbing or adsorbing low-molecular organic compounds. Therefore, as compared with glass containers, plastic containers are often limited for their applications and forms.

For example, in case where plastic containers are used for packing carbonated drinks such as beers and others, or wines, oxygen will penetrate them to time-dependently oxidize the drinks packed in them. In addition, carbon dioxide gas in the packed carbonated drinks will pass through the plastic containers outside them, and the drinks will go flat.

Therefore, plastic containers are unsuitable to drinks that must not be oxidized, and to carbonated drinks.

On the other hand, in case where plastic containers are used for packing drinks with flavoring ingredients, such as orange juices and others, the flavoring ingredients of low-molecular organic compounds existing in the drinks (for example, limonene and others in orange juices) will be absorbed or adsorbed by them. As a result, the composition of the flavoring ingredients of the packed drinks will be unbalanced, and the quality of the drinks will become poor. For these reasons, plastic containers are unsuitable to drinks with flavoring ingredients.

The recent tendency in the art is toward recycling natural resources, for which the problem is how to collect and recover used containers. In case where plastics are used for returnable containers and used plastic containers are left as such after they are collected, they will absorb or adsorb various low-molecular organic compounds that will give musty odors. Accordingly, using plastics for returnable containers is limited, being different from the case of using glass for returnable containers.

However, as so mentioned hereinabove, plastic containers have the advantages of easy moldability, light weight and low costs. Using plastic containers for packing carbonated drinks, drinks with flavoring ingredients and the

like, or for packing substances that require high purity, or using them as returnable containers, if possible, will be extremely convenient.

To meet the requirements, some techniques such as those mentioned below have been disclosed. Japanese Patent Laid-Open No. 53116/1996 discloses plastic containers with their inner surfaces being coated with a DLC (diamond-like carbon) film. Japanese Patent Laid-Open No. 53117/1996 discloses an apparatus and a method for producing the containers. Japanese Patent Laid-Open No. 258825/1998 discloses an apparatus and a method for producing DLC film-coated plastic containers on an industrial scale. Japanese Patent Laid-Open No. 226884/1998 discloses an apparatus and a method for uniformly coating containers with a DLC film, in which the containers to be coated are so modified that they have branches projecting outward from their outer surfaces.

The DLC film will be referred to as an i-carbon film or a hydrogenated amorphous carbon film (a-C:H) film, including hard carbon films. The DLC film is an amorphous carbon film, having SP3 bonds.

Forming such a DLC film on the inner surfaces of plastic containers will make the resulting plastic containers returnable.

SUMMARY OF THE INVENTION

The present invention is to provide a DLC film having good oxygen gas barrier properties; a DLC film-coated plastic container suitable to drinks sensitive to oxygen and to sparkling drinks, especially that with its inner surface being coated with a DLC film having a uniform thickness; and an apparatus and a method for producing the DLC film-coated plastic container.

The object of the invention is attained by providing an apparatus for producing DLC film-coated plastic containers, which comprises an outer electrode unit disposed outside a plastic container (5), an inner electrode (11) disposed inside the plastic container (5), a degassing unit for reducing the inner pressure of the plastic container (5), a gas feeding unit (12, etc.) for feeding a raw material gas of a carbon source into the plastic container (5) having been degassed by the degassing unit, and a power source unit (8, 9) for applying a voltage between the outer electrode unit and the inner electrode (11) with a carbon source gas being fed into the container (5), thereby to generate plasma to form a DLC film on the inner surface of the plastic container (5), and in which the outer electrode unit comprises a first outer electrode (4) disposed along the bottom of the plastic container (5), and a second outer electrode (3) disposed along the body of the plastic container (5), and the upper edge of the first outer electrode (4) is positioned below the center between the top

and the bottom of the plastic container (5). This apparatus is hereinafter referred to as "apparatus with an outer electrode unit split in two sections". In this aspect of the invention, the outer electrode unit is split into the first outer electrode (4) and the second outer electrode (3), by which a suitable level of power can be applied to each site of the container to be coated. In the apparatus with an outer electrode unit split in two sections of the invention, preferably, the power source unit (8, 9) applies a higher power to the first outer electrode (4) than to the second outer electrode (3). In the preferred embodiment where a higher power is applied to the first outer electrode (4) than to the second outer electrode (3), a DLC film having a suitable thickness can be formed on the entire inner surface of the container (5).

The "bottom" of the plastic container includes not only the "bottom surface" of the container but also the "lower part of the body" thereof. The "lower part of the body" of the container specifically indicates the curved area thereof at which the bottom of the container communicates with the body thereof. The "body" of the plastic container indicates the body part thereof except the "lower part of the body" thereof.

In the apparatus with an outer electrode unit split in two sections, more preferably, the outer electrode unit is provided with a third outer electrode (2) disposed along the

shoulder of the plastic container (5). The apparatus with an outer electrode unit split in two sections of the invention includes the more preferred embodiment, which is hereinafter referred to as "apparatus with an outer electrode unit split in two sections and with a third outer electrode".

The object of the invention is also attained by providing an apparatus for producing DLC film-coated plastic containers, which comprises an outer electrode unit disposed outside a plastic container (5), an inner electrode (11) disposed inside the plastic container (5), a degassing unit for reducing the inner pressure of the plastic container (5), a gas feeding unit (12, etc.) for feeding a raw material gas of a carbon source into the plastic container (5) having been degassed by the degassing unit, and a power source unit (8, 9) for applying a voltage between the outer electrode unit and the inner electrode (11) with a carbon source gas being fed into the container (5), thereby to generate plasma to form a DLC film on the inner surface of the plastic container (5), and in which the outer electrode unit comprises a first outer electrode (4) disposed along the bottom of the plastic container (5), a second outer electrode (3) disposed along the body of the plastic container (5), and a third outer electrode (2) disposed along the shoulder of the plastic container (5). This apparatus is hereinafter referred to as "apparatus with an outer electrode unit split in three sections". In this

aspect of the invention, the outer electrode unit is split into the first outer electrode (4), the second outer electrode (3), and the third outer electrode (2), by which a suitable level of power can be applied to each site of the container to be coated. In the apparatus with an outer electrode unit split in three sections of the invention, preferably, the power source unit (8, 9) applies a higher power to the first outer electrode (4) than to the second outer electrode (3). In the preferred embodiment where a higher power is applied to the first outer electrode (4) than to the second outer electrode (3), a DLC film having a suitable thickness can be formed on the entire inner surface of the container (5).

The object of the invention is also attained by providing an apparatus for producing DLC film-coated plastic containers, which comprises an outer electrode unit disposed outside a plastic container (5), an inner electrode (11) disposed inside the plastic container (5), a degassing unit for reducing the inner pressure of the plastic container (5), a gas feeding unit (12, etc.) for feeding a raw material gas of a carbon source into the plastic container (5) having been degassed by the degassing unit, and a power source unit (8, 9) for applying a voltage between the outer electrode unit and the inner electrode (11) with a carbon source gas being fed into the container (5), thereby to generate plasma to form a DLC film on the inner surface of the plastic container (5),

and in which the outer electrode unit comprises a first outer electrode disposed along the bottom of the plastic container (5), a second outer electrode disposed above the first outer electrode and along the outer periphery of the plastic container (5), and at least two other outer electrodes disposed above the second outer electrode and along the outer periphery of the plastic container (5). This apparatus is hereinafter referred to as "apparatus with an outer electrode unit split in plural sections". In the apparatus with an outer electrode unit split in plural sections of the invention, preferably, the power source unit (8, 9) applies a higher power to the first outer electrode than to the second outer electrode.

For producing DLC film-coated plastic containers, the invention provides a method that comprises disposing a first outer electrode outside a plastic container (5) along the bottom of the plastic container (5) and in such a manner that the upper edge of the first outer electrode is positioned below the center between the top and the bottom of the plastic container (5), disposing a second outer electrode outside the plastic container (5) and along the body of the plastic container (5), disposing an inner electrode (11) inside the plastic container (5), degassing the plastic container (5), then feeding a raw material gas of a carbon source into the plastic container (5), and applying a voltage between the first and second outer electrodes and the inner electrode (11)

thereby to generate plasma to form a DLC film on the inner surface of the plastic container (5). In this method, preferably, a higher power is applied to the first outer electrode than to the second outer electrode.

For producing DLC film-coated plastic containers, the invention provides another method that comprises disposing a first outer electrode outside a plastic container (5) and along the bottom of the plastic container (5), disposing a second outer electrode outside the plastic container (5) and along the body of the plastic container (5), disposing a third outer electrode outside the plastic container (5) and along the shoulder of the plastic container (5), disposing an inner electrode (11) inside the plastic container (5), degassing the plastic container (5), then feeding a raw material gas of a carbon source into the plastic container (5), and applying a voltage between the first, second and third outer electrodes and the inner electrode (11) thereby to generate plasma to form a DLC film on the inner surface of the plastic container (5). In this method, preferably, a higher power is applied to the first outer electrode than to the second outer electrode.

For producing DLC film-coated plastic containers, the invention provides still another method that comprises disposing a first outer electrode outside a plastic container (5) and along the bottom of the plastic container (5), disposing a second outer electrode outside the plastic container (5) and

above the first outer electrode, disposing at least two additional outer electrodes outside the plastic container (5) and above the second outer electrode, disposing an inner electrode (11) inside the plastic container (5), degassing the plastic container (5), then feeding a raw material gas of a carbon source into the plastic container (5), and applying a voltage between the first and second outer electrodes combined with at least two other outer electrodes above the second outer electrode, and the inner electrode (11) thereby to generate plasma to form a DLC film on the inner surface of the plastic container (5). In this method, preferably, a higher power is applied to the first outer electrode than to the second outer electrode.

The object of the invention is also attained by providing a DLC film to be formed on the surface of a plastic molding and having a thickness of from 50 to 400 Å. In this aspect of the invention, the DLC film has a thickness of from 50 to 400 Å. In this, therefore, the oxygen transmission rate through the DLC film is effectively reduced, and the transparency of the DLC film-coated plastic molding is well prevented from being reduced owing to the discoloration of the DLC film. In addition, since the DLC film is prevented from being cracked owing to compression stress applied thereto, the oxygen barrier properties of the DLC film-coated plastic molding are well prevented from being degraded. Further,

since the time for vapor deposition to form the DLC film is shortened, the productivity of the DLC film-coated plastic molding is improved. Preferably, the DLC film having a thickness of from 50 to 400 Å has a hydrogen content of from 16 to 52 hydrogen atomic %, including the preferred embodiment.

The object of the invention is also attained by providing a DLC film to be formed on the surface of a plastic molding and having a hydrogen content of from 16 to 52 hydrogen atomic %.

More preferably, the DLC film thus defined by its thickness and/or its hydrogen content in the manner as above has a density of from 1.2 to 2.3 g/cm^3.

The object of the invention is also attained by providing a plastic container with its inner surface coated with a DLC film formed thereon, in which the DLC film has a thickness of from 50 to 400 Å. In this aspect of the invention, the DLC film has a thickness of from 50 to 400 Å. In this, therefore, the oxygen transmission rate through the DLC film-coated plastic container is effectively reduced, and the transparency of the container is well prevented from being reduced owing to the discoloration of the DLC film. In addition, since the DLC film is prevented from being cracked owing to compression stress applied thereto, the oxygen barrier properties of the DLC film-coated plastic container are well prevented from being degraded. Further, since the time for

vapor deposition to form the DLC film is shortened, the productivity of the DLC film-coated plastic container is improved. Of the DLC film-coated plastic container, preferably, the DLC film has a hydrogen content of from 16 to 52 hydrogen atomic %.

The object of the invention is also attained by providing a DLC film-coated plastic container with its inner surface coated with a DLC film formed thereon, in which the DLC film has a hydrogen content of from 16 to 52 hydrogen atomic %.

Of the DLC film-coated plastic container with its inner surface coated with a DLC film formed thereon and specifically defined by the thickness and/or the hydrogen content thereof, more preferably, the DLC film formed on the inner surface has a density of from 1.2 to 2.3 g/cm^3.

For ensuring easy understanding of the present invention, the numeral references in the drawings attached hereto are referred to as parenthesized herein, which, however, are not to restrict the scope of the invention to only the embodiments illustrated by the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view showing one embodiment of the production apparatus of the invention.

Fig. 2A and Fig. 2B are schematic views both showing one embodiment of the shape of a PET bottle, with Fig. 2A

illustrating the front view of the bottle, and Fig. 2B illustrating the bottom view thereof seen in the direction of the line B-B in Fig. 2A.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to Fig. 1, Fig. 2A, Fig. 2B, and Tables 1 to 7 given below, embodiments of the apparatus for forming and producing a DLC film and a DLC film-coated plastic container of the invention are described hereinunder.

Fig. 1 is a schematic view showing the apparatus of the invention, specifically the electrode constitution therein. As in Fig. 1, the apparatus comprises a stand 1; a shoulder electrode 2 fitted to the stand 1; a body electrode 3; and a bottom electrode 4 detachably fitted to the body electrode 3. As illustrated, the shoulder electrode 2, the body electrode 3 and the bottom electrode 4 each have an inner surface that corresponds to the outer shape profile of the plastic container 5. The shoulder electrode 2 is disposed along the shoulder of the plastic container 5; the body electrode 3 is along the body of the plastic container 5; and the bottom electrode 4 is along the bottom of the plastic container 5. The shoulder electrode 2, the body electrode 3 and the bottom electrode 4 constitute the outer electrode unit for the apparatus illustrated.

When the bottom electrode 4 is fitted to the body electrode 3, then the stand 1, the shoulder electrode 2, the

body electrode 3 and the bottom electrode 4 shall form an airtightly closed system, which functions as a vacuum chamber having a housing space where the plastic container 5 is housed.

As in Fig. 1, an insulator 6 is interposed between the shoulder electrode 2 and the body electrode 3, and the shoulder electrode 2 is electrically insulated from the body electrode 3 via the insulator 6. An O-ring 7 is interposed between the body electrode 3 and the bottom electrode 4. When the bottom electrode 4 is fitted to the body electrode 3 via the O-ring 7 therebetween, the O-ring 7 forms a slight gap between the bottom electrode 4 and the body electrode 3.

In that manner, the bottom electrode 4 is airtightly fitted to the body electrode 3, while being electrically insulated from it.

In the housing space 10, disposed is an inner electrode 11. The inner electrode 11 is inserted into the plastic container 5 housed in the housing space 10. The inner electrode 11 is electrically connected to the ground potential.

The inner electrode 11 is formed to have a hollow (cylindrical) shape. At the lower end of the inner electrode 11, formed is one through-hole (not shown) via which the inside of the inner electrode 11 communicates with the outside thereof. In place of disposing one through-hole at the lower end of the inner electrode 11, a plurality of through-holes (not shown) may be formed around the inner electrode 11, via which the

inside of the inner electrode 11 radially communicates with the outside thereof. A duct 12 is inserted into the inner electrode 11. A raw material gas fed into the inner electrode 11 via the duct 12 is led into the plastic container 5 via the through-hole(s). The duct 12 is made of metal and has electroconductivity. As in Fig. 1, the inner electrode 11 is connected to the ground potential via the duct 12. The inner electrode 11 is supported by the duct 12.

As in Fig. 1, the bottom electrode 4 is connected to the output terminal of a high-frequency oscillator via a matching transformer 8 disposed therebetween. The high-frequency oscillator 9 generates a high-frequency voltage between it and the ground potential. According to this, the high-frequency voltage thus generated is imparted between the inner electrode 11 and the bottom electrode 4. The high-frequency power source is for 13.56 MHz, and the same shall apply hereinunder.

The process of forming a DLC film on the inner surface of the plastic container 5 by the use of the apparatus is described.

The plastic container 5 is so disposed that its bottom is kept in contact with the inner surface of the bottom electrode 4. With the bottom electrode 4 ascending, the plastic container 5 is housed in the housing space 10. In this condition, the inner electrode 11 disposed in the housing space

10 is inserted into the plastic container 5 through the mouth (opening in the upper end) of the plastic container 5.

After the bottom electrode 4 has ascended to a predetermined level to close the housing space 10, the outer periphery of the plastic container 5 is kept in contact with the inner surface of the shoulder electrode 2, the body electrode 3 and the bottom electrode 4. Next, the closed housing space 10 is degassed via the exhaust outlet 1A formed through the stand 1, by the use of a degassing unit (not shown). In that manner, the closed housing space 10 is degassed until the vacuum degree therein reaches the necessary level. Next, a raw material gas (for example, a carbon source gas of aliphatic hydrocarbons, aromatic hydrocarbon, etc.) fed via the duct 12 is introduced into the plastic container 5 through the through-hole(s) of the inner electrode 11.

After the concentration of the raw material gas in the plastic container 5 has reached a predetermined level, the high-frequency oscillator 9 is driven to thereby impart a high-frequency voltage between the inner electrode 11 and the outer electrode unit, and plasma is generated in the plastic container 5. Through the process, a DLC film is formed on the inner surface of the plastic container 5.

As in the manner as above, the DLC film is formed on the inner surface of the plastic container 5 through plasma CVD.

Owing to the plasma formed between the outer electrode unit and the inner electrode 11, electrons deposit on the inner surface of the insulated outer electrode unit, thereby causing potential depression to a predetermined level. As a result, the carbon and hydrogen atoms constituting the hydrocarbon of the raw material gas that exists in the plasma are ionized to be cations. The cations collide at random against the inner surface of the plastic container 5 that runs along the inner surface of the outer electrode unit. In that condition, the neighboring carbon atoms, or the neighboring carbon and hydrogen atoms bond to each other, or the hydrogen atoms having once bonded to carbon atoms separate from them through sputtering. As a result of the process, a DLC film of extremely dense DLC is formed on the inner surface of the plastic container 5.

As so mentioned hereinabove, the output terminal of the high-frequency oscillator 9 is connected to only the bottom electrode 4 via the matching transformer 8. In addition, a gap is formed between the bottom electrode 4 and the body electrode 3, and the bottom electrode 4 is electrically insulated from the body electrode via the gap. Further, the insulator 6 is interposed between the body electrode 3 and the shoulder electrode 2, and the body electrode 3 is electrically insulated from the shoulder electrode 2 via the insulator 6. Accordingly, the high-frequency power to be applied to the body

electrode 3 and the shoulder electrode 2 shall be smaller than that to be applied to the bottom electrode 4. However, since the bottom electrode 4 and the body electrode 3, and also the body electrode 3 and the shoulder electrode 2 are in capacitive coupling between them via the gap therebetween, some degree of high-frequency power is applied also to the body electrode 3 and to the shoulder electrode 2.

In general, the bottom of plastic containers such as bottles and others has a complicated profile, on which, therefore, a DLC film having a satisfactory thickness is difficult to form. Owing to the production problem, the bottom of plastic containers is often oriented to an unsatisfactory degree, and its gas barrier properties are often poor. Accordingly, even after a DLC film has been formed on the inner surface of plastic containers, the gas barrier properties of the bottom of the containers are often still poor.

Our experiments carried out for forming a DLC film on the inner surface of a plastic bottle, a type of plastic containers, with applying the same high-frequency power to the entire outer electrode unit composed of the shoulder electrode 2, the body electrode 3 and the bottom electrode 4 revealed that the DLC film formed on the inner surface area from the mouth to the shoulder of the plastic bottle was thick while that formed around the shoulder thereof was relatively thin and that formed on the bottom thereof was extremely thin. The

gas barrier properties of the DLC film-coated bottle are significantly poor as a whole since the gas barrier properties of the bottom of the non-coated bottle itself are naturally poor, as so mentioned hereinabove. In order to ensure the DLC film entirely having a satisfactory thickness, the time for the coating operation will be prolonged to 20 to 30 seconds, which, however, increases the production costs. Another problem in the tested process is that, in the area coated with such a thick DLC film, the DLC film is easy to peel off. Still another problem is that the bottles being coated with the DLC film are often deformed during the prolonged coating time or by the increased high-frequency power, and the deformed bottles are no more in practical use. We have found that the suitable high-frequency power to be applied falls between 400 and 500 W or so.

In addition, in the tested process, the adhesiveness of the DLC film to the inner surface of the coated containers was low, and the density of the DLC film formed was low.

Anyhow, in case where a uniform high-frequency power is applied to the entire outer electrode unit as in the tested process, the gas barrier properties of the coated plastic bottles could be improved only by about 2 to 6 times those of the non-coated ones.

As opposed to this, in the production apparatus of the embodiment mentioned above, a larger high-frequency power can

be applied to the bottom of the plastic container than to the body and the shoulder thereof, and therefore a uniform DLC film can be formed on the entire inner surface of the bottle. In addition, a thicker DLC film can be formed on the inner surface of the bottom of the plastic container of which the gas barrier properties are naturally poor. Accordingly, the DLC film-coated plastic container thus produced can have effectively improved gas barrier properties as a whole of the container. In the embodiment mentioned above, the power to be applied can be increased to 1200 to 1400 W. Accordingly, the coating time could be shortened and the production costs could be reduced.

In the embodiment mentioned above, the high-frequency power to be applied to the area around the mouth of the container and that around the shoulder thereof can be lowered while that to be applied to the area around the bottom of the container can be increased to a satisfactory degree. In that condition, therefore, the plastic containers being coated are prevented from being deformed. Other advantages are that a dense DLC film can be formed in the embodiment and the adhesiveness of the thus-formed DLC film to the inner surface of the plastic container is high.

In the embodiment mentioned above, the shoulder electrode 2, the body electrode 3 and the bottom electrode 4 are so constructed in series that they are completely insulated from each other for a direct current to be applied thereto,

but the illustrated construction of the outer electrode unit disposition is not limitative. As the case may be, the electrodes may be connected to each other via resistive or capacitive elements or the like therebetween. In short, the necessary level of high-frequency power shall be applied to each outer electrode, depending on the parts of the container to be coated. For example, a plurality of high-frequency oscillators may be prepared and so disposed that they could separately apply a different level of high-frequency power to each electrode of the shoulder electrode 2, the body electrode 3 and the bottom electrode 4. Alternatively, a single high-frequency oscillator may be connected to every electrode separately via a plurality of different matching transformers so that it can impart different levels of high-frequency power to the different electrodes.

In the embodiment mentioned above, the outer electrode unit is split into three sections. Apart from this, the outer electrode unit may be split into three sections, or even into four or more sections.

In the embodiment mentioned above, the container to be coated has a bottom profile that is hardly coated with a DLC film, which, however, is not limitative. Naturally, the high-frequency power distribution to be applied to containers can be properly controlled, depending on the shape of the containers, whereby a good DLC film can be formed uniformly

on the entire inner surface of the containers.

In the production apparatus of the invention, plastic containers suitable to returnable applications can be produced, which, however, are not limitative. Needless-to-say, the plastic containers produced in the apparatus can be for one-way applications as disposable containers (that is, the containers packed and used once are not recovered but are discarded).

The invention is described in more detail with reference to the following Examples, which, however, are not intended to restrict the scope of the invention.

EXAMPLES

Example 1:

This is to demonstrate the formation of a DLC film on the inner surface of 500 ml PET (polyethylene terephthalate) bottles by the use of the apparatus mentioned above under different conditions mentioned below. The coated bottles were tested for their properties, and the data obtained are given below.

Table 1 shows the condition for plasma CVD employed herein, and the dimension and the shape of the PET bottles and others coated herein. Table 2 shows the methods for testing and evaluating the bottles of which the inner surface was coated with a DLC film. Table 3 shows the film-forming conditions for which toluene was used as the raw material gas, and the test data of the coated bottles. Table 4 shows the film-

forming conditions for which acetylene was used as the raw material gas, and the test data of the coated bottles.

Table 1A - Condition for Plasma CVD

(1) High-frequency Power: 500 to 1500 W.
(2) Vacuum Degree: 0.01 to 0.07 Torr.
(3) Gas Flow Rate: 1.7 to 31 cc/min.
(4) Raw Material Gas: toluene, acetylene.
(5) Plasma Stability: evaluated according to the following three-rank criteria.
O: Plasma formed was kept stable.
Δ: Plasma formed was unstable, but was enough to form samples.
×: No plasma was formed.
(6) Filming Time: 6 to 40 seconds.
(7) Method of Discharging Outer electrode Unit:
<1> to the whole.
<2> only to the body and the bottom.
<3> only to the bottom.

Table 1B - Dimension of Plastic Bottles

Height	Bottles		
	500 ml PET bottle, 32 g, wall thickness 0.4 mm	700 ml PET bottle, 62 g, wall thickness 0.6 mm	500 ml PP bottle, 36 g, wall thickness 0.8 mm
Mouth (mm)	22.4	24.5	29.0
Shoulder (mm)	62.1	175.0	104.5
Body (mm)	92.0		
Bottom (mm)	30.5	30.5	30.5
Total Height (mm)	207.0	230.0	164.0
bottom/(shoulder + body + bottom), %	16.5	14.8	22.6

Table 2 - Test Methods

(1) Appearance Evaluation: DLC films formed are transparent and brownish. DLC film-coated bottles are macroscopically checked for the color density and the film thickness uniformity, and are ranked in three ranks, O, Δ and ×.
(2) Bottle Deformation: Bottles coated with a large high-frequency power applied thereto and for a long period of time for exposure to plasma are deformed by the heat of plasma. Based on the degree of deformation, the coated bottles are ranked in three ranks, O, Δ and ×.
(3) Oxygen Transmission Rate: Measured with Modern Control's Oxtran, at 22°C, 60 % RH.

Table 3 (raw material gas: toluene)

Condition						Test Results		
Discharging Method	High-Frequency Power (W)	Vacuum Degree (Torr)	Gas Flow Rate (cc/min)	Plasma Stability	Period for Exposure to Plasma (sec)	Appearances	Bottle Deformation	Oxygen Transmission Rate (ml/day/bottle)
Control	-	-	-	-	-	-	O	0.033
Whole	400	0.03	6.3	×	10	×	O	0.029
Whole	500	0.02	3.7	× - Δ	10	×	O	0.022
Whole	500	0.03	3.8	× - Δ	10	×	O	0.022
Whole	800	0.03	3.8	Δ - O	10	×	Δ	0.020
Whole	1000	-	-	×	-	-	-	-
Bottom, Body	300	0.03	6.3	×	40	×	Δ	0.031
Bottom, Body	700	0.03	6.3	× - Δ	10	×	O	0.026
Bottom, Body	1000	0.03	6.3	Δ - O	10	Δ	Δ	0.006
Bottom, Body	1300	-	-	×	-	-	-	-
Bottom	500	0.02	2.7	× - Δ	30	×	O	0.022
Bottom	800	0.03	5.6	× - Δ	15	Δ	O	0.023
Bottom	1000	0.03	6.4	Δ - O	10	Δ	O	0.018
Bottom	1000	0.02	4.6	Δ - O	12	Δ	O	0.010
Bottom	1200	0.02	2.7	O	10	O	O	0.004
Bottom	1200	0.02	4.6	O	10	O	O	0.004
Bottom	1300	0.02	2.7	O	8	O	O	0 004
Bottom	1400	0.01	1.7	Δ - O	6	O	O	0.007
Bottom	1500	0.03	6.4	× - Δ	7	Δ	Δ	0.006

Table 4 (raw material gas: acetylene)

Condition						Test Results		
Discharging Method	High-Frequency Power (W)	Vacuum Degree (Torr)	Gas Flow Rate (cc/min)	Plasma Stability	Period for Exposure to Plasma (sec)	Appearances	Bottle Deformation	Oxygen Transmission Rate (ml/day/bottle)
Control	-	-	-	-	-	-	O	0.033
Whole	500	0.05	31	Δ - O	15	×	O	0.021
Whole	800	0.05	31	× - Δ	8	×	O	0.016
Whole	1000	-	-	×	-	-	O	-
Bottom, Body	500	0.05	31	Δ - O	15	×	O	0.018
Bottom, Body	800	0.05	31	O	10	Δ	Δ	0.009
Bottom, Body	1000	0.05	31	Δ - O	7	Δ	O	0.005
Bottom, Body	1500	-	-	×	-	-	O	-
Bottom	500	0.07	31	× - Δ	20	×	O	0.017
Bottom	800	0.06	31	× - Δ	15	Δ	O	0.012
Bottom	1000	0.05	31	O	10	O	O	0.002
Bottom	1500	0.05	31	O	8	O	Δ	0.005
Bottom	2000	0.05	31	Δ - O	6	O	Δ	0.006

In Table 1B showing the dimension of plastic bottles, the "bottom/(shoulder + body + bottom)" indicates the ratio of the height of the bottom, which faces the bottom electrode 4, to the total height of the bottle. Precisely, it indicates the value obtained by dividing the "length from the bottom of the bottle to the top edge of the bottom electrode 4" by the "total height of the bottle (that is, the length from the bottom to the top edge of the bottle)", in terms of percentage.

In Table 1B showing the dimension of plastic bottles, "700 ml PET bottle" and "500 ml PP (polypropylene) bottle" were prepared for testing them. In the columns of these bottles, the dimensions of the bottles and the site of the bottom electrode applied to the bottles correspond to those in the column of "500 ml PET bottle". The data in Table 3 and Table 3 are of the 500 ml PET bottles tested under the film-forming conditions indicated therein.

In "(7) Method of Discharging Outer Electrode Unit" in Table 1A, the case of "<1> to the whole" is such that the shoulder electrode 2, the body electrode 3 and the bottom electrode 4 are all electrically short-circuited to each other and the same high-frequency power is applied to all these electrodes at the same time. The case of "<2> only to the body and the bottom" is such that the body electrode 3 and the bottom electrode 4 are both electrically short-circuited to each other while the shoulder electrode 2 is insulated from the body

electrode 3, and the same high-frequency power is applied to both the body electrode 3 and the bottom electrode 4 at the same time. The case of "<3> only to the bottom" is the method of the present invention, for which the shoulder electrode 2, the body electrode 3 and the bottom electrode 4 are all electrically insulated from each other, and the high-frequency power is applied to only the bottom electrode 4. These discharging methods are in the column of "Discharging Method" in Table 3 and Table 4.

In Table 2 indicating the details of "(1) Appearance Evaluation" and "(2) Bottle Deformation", "O" means the best and "×" means the worst. The test results are in the corresponding columns in Table 3 and Table 4. From the data given in Table 3 and the Table 4, it is obvious that the discharging method "only to the bottom" is better than the other discharging methods.

Example 2:

This is to demonstrate the formation of a thinner DLC film on the inner surface of 500 ml PET (polyethylene terephthalate) bottles than in Example 1, under different film-forming conditions as in Table 5 below, for which is used the apparatus mentioned above. The coated bottles were tested and the test data obtained are given in Table 5.

In Example 2, the period for exposure to plasma is relatively shortened, and therefore the DLC film formed is

thin.

Table 5

Test No.	Period for Exposure to Plasma (sec)	Film Thickness (Å)	Oxygen Transmission Rate (ml/day/bottle)
1	0	0	0.033
2	2	50 - 75	0.008
3	4	90 - 160	0.007
4	6	150 - 230	0.004 - 0.006
5	8	200 - 300	0.004
6	10	250 - 380	0.003 - 0.004

The condition for exposure to plasma in Tests Nos. 1 to 6 is as follows: Acetylene was used as the raw material gas. For discharging, a high-frequency power was applied to only the bottom electrode 4. Precisely, the shoulder electrode 2, the body electrode 3 and the bottom electrode 4 were electrically insulated from each other, and a high-frequency power was applied to only the bottom electrode 4. The high-frequency power was 1300 W; the vacuum degree was 0.05 Torr (6.66 Pa); and the gas flow rate was 31 ml/min. Test No. 1 is a control, non-coated PET bottle.

Table 5 shows the period for exposure to plasma, the thickness of the DLC film formed, and the oxygen transmission rate through the film in Tests Nos. 1 to 6. Fig. 2A and Fig. 2B are schematic views showing the shape of the PET bottle used in the tests herein.

In Figs. 2A and 2B, the PET bottle 100 has a height, A, of 207 mm, which is the length from the top to the bottom

of the bottle 100. In Figs. 2A and 2B, the dimensions of the other parts of the bottle are as follows: B = 68.5 mm, C = 34.5 mm, D = 88 mm, E = 2 mm, F = 22.43 mm, G = 24.94 mm, H = 33 mm, J = 67.7 mm, K = 26.16 mm, L = 66.5 mm, M = 21.4 mm, N = 46 mm. The thickness of the wall of the PET bottle 100 is 0.4 mm.

The thickness of the DLC film formed on the inner surface of the shoulder, the body and the bottom of the PET bottle 100 was measured. In Table 5, the data of the DLC film thickness indicate the range between the lowest value and the highest value measured.

As in Table 5, the oxygen transmission rate through the control, non-coated PET bottle in Test No. 1 is 0.033 ml/day/bottle, while that through the PET bottle in Test No. 2, which has a DLC film of from 50 to 75 Å thick on its inner surface, is 0.008 ml/day/bottle. From this, it is understood that the oxygen transmission rate through the bottle with such a thin DLC film of from 50 to 75 Å or so in thickness formed on its inner surface is reduced to about 1/4 or so of that through the non-coated bottle. As in Table 5, it is understood that the oxygen transmission rate through the PET bottles in Tests Nos. 3 to 6 with a thicker DLC film formed on their inner surface is further reduced. The data obtained herein support the effective reduction in the oxygen transmission rate through the DLC film-coated PET bottles in which the thickness of the

DLC film is relatively small, falling between 50 and 400 Å or so.

The PET bottles of Tests Nos. 2 to 6 each having a thin DLC film formed on the inner surface have the following advantages: The first is that the bottles could be transparent. In general, DLC films look pale yellow, but look black when too thick. Therefore, bottles with their inner surface coated with such a thick DLC film shall lose transparency. The second is that the thin DLC film formed on the inner surface of the bottles is hardly cracked. Contrary to this, thick DLC films will receive large compression stress and will be readily cracked, and the oxygen barrier properties of bottles of which the inner surface is coated with such a cracked DLC film will be not good. The third is that the time for vapor deposition to form such a thin DLC film is short, and the productivity of the DLC film-coated bottles is high.

The oxygen transmission rate through the DLC film-coated bottles shown in Table 5 was measured by the use of Modern Control's Oxtran, at 22°C and 60 % RH. The thickness of the DLC film was measured by the use of a profilometer, Tenchol's Alpha-step 500.

Example 3:

A DLC film was formed on the inner surface of 500 ml PET bottles by the use of the apparatus mentioned above. The details of the film-forming condition employed herein are given

in Table 6. The DLC film-coated bottles were tested and the test data are in Table 6. With reference to the data in Table 6, the coated bottles are discussed in point of the density of the DLC film.

Table 6

Test No.	Discharging Method	High-Frequency Power Applied	Part of Bottle	Thickness Å	Volume 10^{-3} cm^3	Weight mg	Density g/cm^3	Oxygen Transmission Rate ml/day/bottle
7	whole	800 W	shoulder	318	0.387	0.727	1.88	-
			body	213	0.393	0.578	1.47	
			bottom	257	0.249	0.336	1.35	
8	whole	1200 W	shoulder	432	0.526	0.737	1.40	-
			body	232	0.429	0.627	1.46	
			bottom	292	0.283	0.393	1.39	
9	bottom	800 W	shoulder	277	0.377	0.788	2.09	0 003
			body	219	0.405	0.493	1.22	
			bottom	215	0.209	0.334	1.59	
10	bottom	1200 W	shoulder	301	0.367	0.847	2.30	0.003
			body	197	0.364	0.730	2.01	
			bottom	304	0.295	0.437	1.48	

The condition for exposure to plasma in Tests Nos. 7 to 10 is as follows: Acetylene was used as the raw material gas. For discharging, the high-frequency power as in Table 6 was applied to only the bottom electrode 4. Precisely, the shoulder electrode 2, the body electrode 3 and the bottom electrode 4 were electrically insulated from each other, and the high-frequency power was applied to only the bottom electrode 4. The vacuum degree was 0.05 Torr (6.66 Pa); the gas flow rate was 31 ml/min; and the time for exposure to plasma was 8 seconds.

The data of the density of the DLC film formed are given in Table 6. In the column of "Discharging Method" in Table 6, the case of "whole" is such that the shoulder electrode 2, the body electrode 3 and the bottom electrode 4 are all electrically short-circuited to each other and the same high-frequency power is applied to all these electrodes at the same time (Tests Nos. 7 and 8). The case of "bottom" is such that the shoulder electrode 2, the body electrode 3 and the bottom electrode 4 are all electrically insulated from each other, and the high-frequency power is applied to only the bottom electrode 4 (Tests Nos. 9 and 10).

The column of "High-Frequency Power Applied" indicates the high-frequency power applied in each Test. In Table 6, given are the thickness, the volume, the weight and the density of the DLC film formed on the inner surface of each part of

shoulder, body and bottom of the PET bottle in each Test. The part of the PET bottle corresponds to the expression of "shoulder", "body" and "bottom" in the column of "Part of Bottle" in Table 6.

The oxygen transmission rate through the DLC film-coated bottles shown in Table 6 was measured by the use of Modern Control's Oxtran, at 22°C and 60 % RH. The thickness of the DLC film was measured by the use of a profilometer, Tenchol's Alpha-step 500. The surface area of the PET bottle was calculated through CAD, based on the drawing of the PET bottle.

To measure the weight of the DLC film, the film-coated PET bottle 100 was divided into three parts, shoulder, body and bottom. Next, each part was immersed in an aqueous solution of 4 % NaOH in a beaker, and reacted at room temperature for 10 to 12 hours or so, whereby the DLC film was peeled. Next, the solution was filtered through a milli-pore filter of polytetrafluoroethylene (pore size: 0.5 μm), and the deposit remaining on the filter was dried at 105°C. The weight of the milli-pore filter with the dry deposit thereon was measured. The weight of the milli-pore filter alone was subtracted from the thus-measured weight to obtain the weight of the peeled DLC film alone. Since the NaOH solution used herein contains an impurity residue, the blank value of the NaOH solution alone was obtained. Based on the blank value, the weight of the DLC film was corrected.

The density of the DLC film was obtained according to the following formula (1):

Density = weight/(surface area × thickness) (1)

As in Table 6, there is found no significant difference in the density of the DLC films formed on different parts, depending on the high-frequency power applied and on the parts of the PET bottle, and the density of the DLC films falls between 1.2 and 2.3 g/cm^3.

Example 4:

A DLC film was formed on the inner surface of 500 ml PET bottles by the use of the apparatus mentioned above. The DLC film-coated bottles were tested and the test data are in Table 7. With reference to the data in Table 7, the coated bottles are discussed in point of the hydrogen content of the DLC film.

Table 7 (unit: hydrogen atomic %)

Test No.	High-Frequency Power Applied	Part of Bottle	Density (g/cm^3)		
			1.2	1.8	2.3
11	discharging at bottom 800 W	shoulder	28.6	26.3	25.1
		body	18.6	17.2	16.1
		bottom	27.4	25.5	24.1
12	discharging at bottom 1200 W	shoulder	51.9	49.3	-
		body	50.2	47.1	-
		bottom	39.1	37.2	35.8

In Tests Nos. 11 and 12, a glass substrate (length: 23 mm, width: 19 mm, thickness: 0.5 mm) was fitted to a predetermined region of the shoulder, the body and the bottom of the PET bottles. Since PET contains hydrogen, the hydrogen content of PET itself will bring about an error in the data of the hydrogen content of the DLC film to be measured herein. To evade the error, the glass substrate was used herein in measuring the hydrogen content of the DLC film formed on the PET bottles. The glass substrate was fitted to each part of the bottle via the metal plug fixed to the outer electrode unit.

In Fig. 2A, "P" indicates the upper region of the shoulder; "Q" indicates the middle region of the body; and "R" indicates the lower region of the bottom. The lower edge of the shoulder region P is spaced upward by 125 mm from the bottom of the PET bottle; and the upper edge of the shoulder region P is spaced upward by 144 mm from the bottom of the PET bottle. The lower edge of the body region Q is spaced upward by 65 mm from the bottom of the PET bottle; and the upper edge of the body region Q is spaced upward by 84 mm from the bottom of the PET bottle. The lower edge of the bottom region R is spaced upward by 11 mm from the bottom of the PET bottle; and the upper edge of the bottom region R is spaced upward by 30 mm from the bottom of the PET bottle.

To produce plasma, acetylene was used as the raw material gas in Tests Nos. 11 and 12, in which the plasma

discharging was applied to the bottom of the bottles. Precisely, in these, the shoulder electrode 2, the body electrode 3 and the bottom electrode 4 were all electrically insulated from each other, and the predetermined high-frequency power was applied to only the bottom electrode 4. The vacuum degree was 0.05 Torr (6.66 Pa); and the gas flow rate was 31 ml/min. In Test No. 11, the high-frequency power was 800 W; and in Test No. 12, it was 1200 W.

Table 7 shows the data of the hydrogen content of the DLC film formed on the glass substrate fitted to the shoulder region P, the body region Q and the bottom region R of the PET bottle. In Table 7, the "shoulder", "body" and "bottom" in the column of "Part of Container" indicate the shoulder region P, the body region Q and the bottom region R, respectively, of the PET bottle.

As in Table 6, the density of DLC films varies within the range falling between 1.22 and 2.30 g/cm^3. Therefore, the hydrogen content of the DLC film formed herein was measured in different parts of the film having a density of 1.2, 1.8 and 2.3 g/cm^3.

To determine the hydrogen content of the DLC films, the hydrogen concentration % (the proportion of the number of hydrogen atoms) in each DLC film was measured through elastic recoil detection analysis, for which was used an analyzer, Shimadzu's IBA-9900 EREA.

As in Table 7, the hydrogen content of the DLC films increases with the increase in the high-frequency power applied. In addition, it is seen that the hydrogen content of the DLC films decreases in some degree with the increase in the density of the films.

In the embodiment mentioned above, the plasma was generated by the high-frequency power applied to the outer electrode unit, to thereby form DLC films. However, the method of forming DLC films in the invention is not limited to the illustrated case. For example, the plasma for forming DLC films may be generated by microwave discharging.

Not limited to PET or PP containers as in the illustrated embodiment, the DLC films of the invention are applicable to various plastic containers with no limitation. Needless-to-say, the DLC films are applicable to any others than containers.

The "DLC film-coated plastic containers" referred to herein are meant to indicate plastic containers coated with a DLC film.

While the invention has been described in detail and with reference to specific embodiments thereof, it will be apparent to one skilled in the art that various changes and modifications can be made therein without departing from the spirit and scope thereof.

What is claimed is:

1. An apparatus for producing DLC (diamond-like carbon) film-coated plastic containers, which comprises an outer electrode unit disposed outside a plastic container, an inner electrode disposed inside the plastic container, a degassing unit for reducing the inner pressure of the plastic container, a gas feeding unit for feeding a raw material gas of a carbon source into the plastic container having been degassed by the degassing unit, and a power source unit for applying a voltage between the outer electrode unit and the inner electrode with a carbon source gas being fed into the container, thereby to generate plasma to form a DLC film on the inner surface of the plastic container; wherein the outer electrode unit comprises a first outer electrode disposed along the bottom of the plastic container, and a second outer electrode disposed along the body of the plastic container, and the upper edge of the first outer electrode is positioned below the center between the top and the bottom of the plastic container.

2. The apparatus for producing DLC film-coated plastic containers as claimed in claim 1, wherein the power source unit applies a higher power to the first outer electrode than to the second outer electrode.

3. The apparatus for producing DLC film-coated plastic containers as claimed in claim 1 or 2, wherein the outer

electrode unit is provided with a third outer electrode disposed along the shoulder of the plastic container.

4. An apparatus for producing DLC film-coated plastic containers, which comprises an outer electrode unit disposed outside a plastic container, an inner electrode disposed inside the plastic container, a degassing unit for reducing the inner pressure of the plastic container, a gas feeding unit for feeding a raw material gas of a carbon source into the plastic container having been degassed by the degassing unit, and a power source unit for applying a voltage between the outer electrode unit and the inner electrode with a carbon source gas being fed into the container, thereby to generate plasma to form a DLC film on the inner surface of the plastic container; wherein the outer electrode unit comprises a first outer electrode disposed along the bottom of the plastic container, a second outer electrode disposed along the body of the plastic container, and a third outer electrode disposed along the shoulder of the plastic container.

5. An apparatus for producing DLC film-coated plastic containers, which comprises an outer electrode unit disposed outside a plastic container, an inner electrode disposed inside the plastic container, a degassing unit for reducing the inner pressure of the plastic container, a gas feeding unit for feeding a raw material gas of a carbon source into the plastic container having been degassed by the degassing unit, and a

power source unit for applying a voltage between the outer electrode unit and the inner electrode with a carbon source gas being fed into the container, thereby to generate plasma to form a DLC film on the inner surface of the plastic container; wherein the outer electrode unit comprises a first outer electrode disposed along the bottom of the plastic container, a second outer electrode disposed above the first outer electrode and along the outer periphery of the plastic container, and at least two other outer electrodes disposed above the second outer electrode and along the outer periphery of the plastic container.

6. The apparatus for producing DLC film-coated plastic containers as claimed in claim 4 or 5, wherein the power source unit applies a higher power to the first outer electrode than to the second outer electrode.

7. A method for producing DLC film-coated plastic containers, which comprises disposing a first outer electrode outside a plastic container along the bottom of the plastic container and in such a manner that the upper edge of the first outer electrode is positioned below the center between the top and the bottom of the plastic container, disposing a second outer electrode outside the plastic container and along the body of the plastic container, disposing an inner electrode inside the plastic container, degassing the plastic container, then feeding a raw material gas of a carbon source into the

plastic container, and applying a voltage between the first and second outer electrodes and the inner electrode thereby to generate plasma to form a DLC film on the inner surface of the plastic container.

8. The method for producing DLC film-coated plastic containers as claimed in claim 7, wherein a higher power is applied to the first outer electrode than to the second outer electrode.

9. A method for producing DLC film-coated plastic containers, which comprises disposing a first outer electrode outside a plastic container and along the bottom of the plastic container, disposing a second outer electrode outside the plastic container and along the body of the plastic container, disposing a third outer electrode outside the plastic container and along the shoulder of the plastic container, disposing an inner electrode inside the plastic container, degassing the plastic container, then feeding a raw material gas of a carbon source into the plastic container, and applying a voltage between the first, second and third outer electrodes and the inner electrode thereby to generate plasma to form a DLC film on the inner surface of the plastic container.

10. A method for producing DLC film-coated plastic containers, which comprises disposing a first outer electrode outside a plastic container and along the bottom of the plastic container, disposing a second outer electrode outside the

plastic container and above the first outer electrode, disposing at least two additional outer electrodes outside the plastic container and above the second outer electrode, disposing an inner electrode inside the plastic container, degassing the plastic container, then feeding a raw material gas of a carbon source into the plastic container, and applying a voltage between the first and second outer electrodes combined with at least two other outer electrodes above the second outer electrode, and the inner electrode thereby to generate plasma to form a DLC film on the inner surface of the plastic container.

11. The method for producing DLC film-coated plastic containers as claimed in claim 9 or 10, wherein a higher power is applied to the first outer electrode than to the second outer electrode.

12. A DLC film to be formed on the surface of a plastic molding and having a thickness of from 50 to 400 Å.

13. The DLC film as claimed in claim 12, which is formed on the surface of a plastic molding and has a hydrogen content of from 16 to 52 hydrogen atomic %.

14. A DLC film to be formed on the surface of a plastic molding and having a hydrogen content of from 16 to 52 hydrogen atomic %.

15. The DLC film as claimed in claim 12, 13 or 14, which has a density of from 1.2 to 2.3 g/cm^3.

16. A DLC film-coated plastic container having a DLC film on its inner surface, wherein the DLC film has a thickness of from 50 to 400 Å.

17. The DLC film-coated plastic container as claimed in claim 16, wherein the DLC film has a hydrogen content of from 16 to 52 hydrogen atomic %.

18. A DLC film-coated plastic container having a DLC film on its inner surface, wherein the DLC film has a hydrogen content of from 16 to 52 hydrogen atomic %.

19. The DLC film-coated plastic container as claimed in claim 16, 17 or 18, wherein the DLC film has a density of from 1.2 to 2.3 g/cm^3.

ABSTRACT

Disclosed is an apparatus for producing DLC film-coated plastic containers, which comprises an outer electrode unit disposed outside a plastic container, an inner electrode disposed inside the plastic container, a duct through which a raw material gas of a carbon source is fed into the plastic container having been degassed, and a high-frequency oscillator for applying a voltage between the outer electrode unit and the inner electrode with a carbon source gas being fed into the container, thereby to generate plasma to form a DLC film on the inner surface of the plastic container. In the apparatus, the outer electrode unit comprises a bottom electrode disposed along the bottom of the plastic container, and a body electrode disposed along the body of the plastic container, and the upper edge of the bottom electrode is positioned below the center between the top and the bottom of the plastic container. DLC films having good oxygen barrier properties, and DLC film-coated plastic containers suitable to oxygen-sensitive drinks and to sparkling drinks are produced by the use of the apparatus. Also disclosed is a method for producing a DLC film on the inner surface of a plastic container by the use of the apparatus.

FIG.1

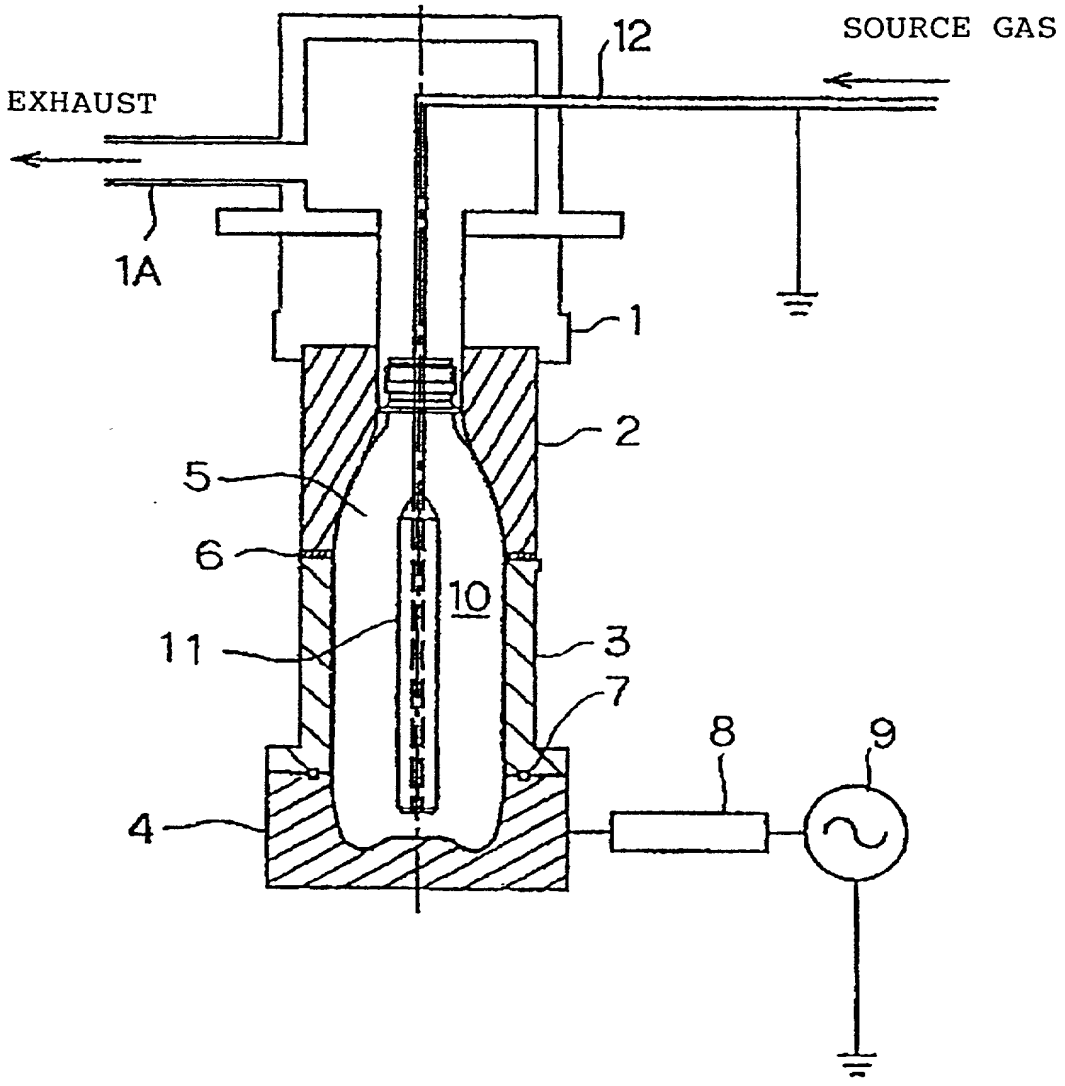
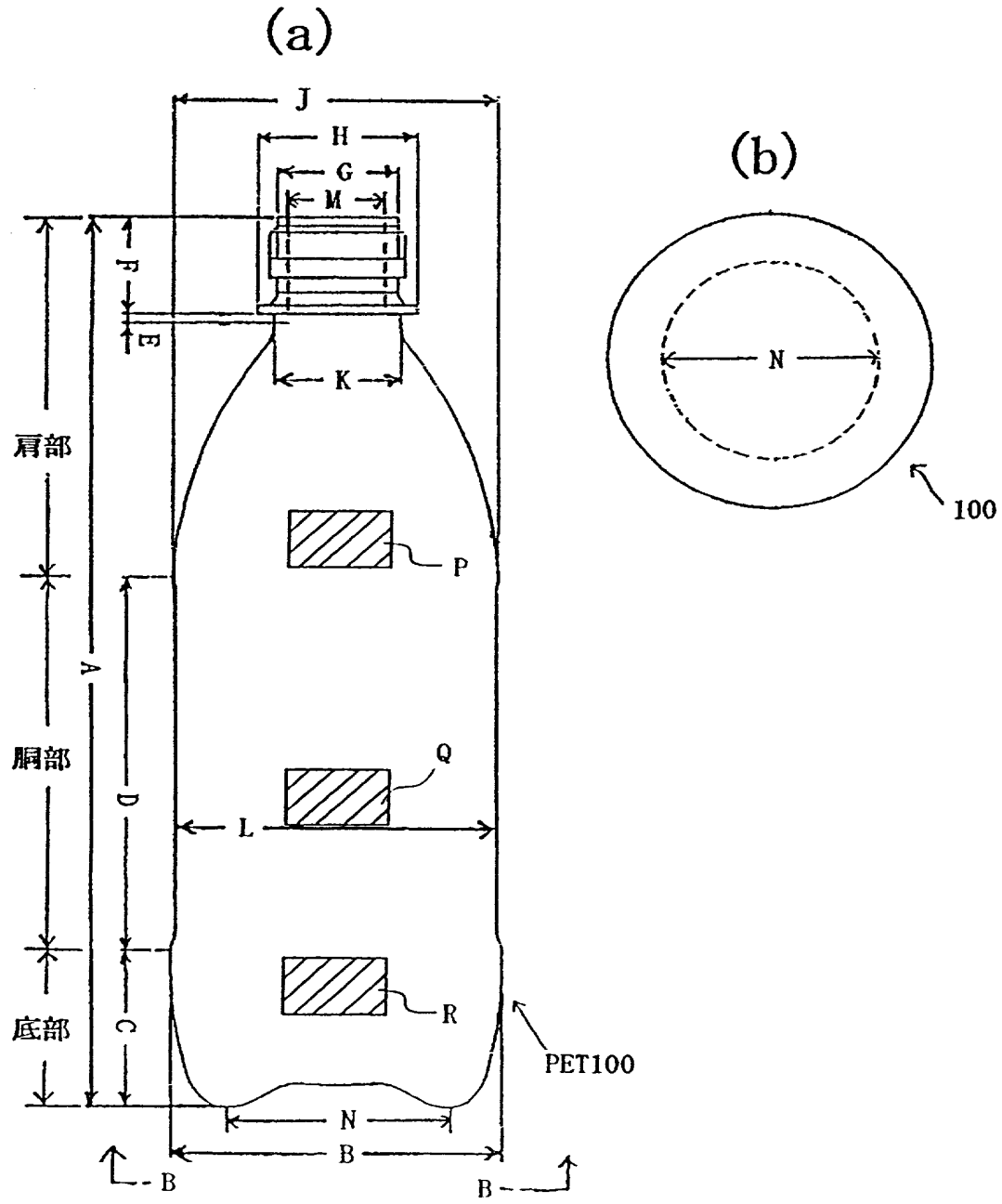


FIG.2



Docket No: _____

APPLICATION FOR UNITED STATES LETTERS PATENT
DECLARATION, POWER OF ATTORNEY, AND PETITION

As a below-named inventor, I declare that:

My residence, post office address and citizenship are as stated next to my name; I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the invention which is described and which is claimed in the specification, entitled: DLC FILM, DLC FILM-COATED PLASTIC CONTAINER, APPARATUS FOR PRODUCING IT, AND METHOD FOR PRODUCING IT.

The specification [ ] is attached hereto [ ] was filed on _____, as Application Serial No. _____.

I hereby state that I have reviewed and understand the contents of said specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.[1]

COUNTRY	APPLICATION NUMBER	DATE (Day, Month, Year)	PRIORITY CLAIMED UNDER 35 U.S.C. 119
Japan	11/139211	19,05,99	Yes [X] No [ ]
Japan	11/299806	21,10,99	Yes [X] No [ ]
Japan	2000/48386	24,02,00	Yes [X] No [ ]

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

[1] In Non-Convention cases, a listing of all filings and current status of cases filed more than a year before the U.S. filing is required to comply with 37 CFR 1.56(a). Such a listing may be attached.

APPLICATION SERIAL NO.	FILING DATE	STATUS
355969	19,08,99	U.S.Patent 6,294,226
776703	25,04,97	U.S.Patent 5,798,139

I hereby appoint my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the U.S. Patent & Trademark Office connected therewith:

(7) Edward A. Hedman, Reg. No. 22,120; Thomas M. Gibson, Reg. No. 24,638; James V. Costigan, Reg. No. 25,669; Kenneth F. Florek, Reg. No. 33,173; Alan B. Clement, Reg. No. 34,563; Martin P. Endres, Reg. No. 35,498 and Timothy X. Gibson, Reg. No. 40,618.

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The undersigned declares further that all statements made herein of his own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

INVENTOR(S)	DATE	RESIDENCE AND P.O. ADDRESS
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3-00 Name: KAGE, Tsuyoshi Signature: Tsuyoshi Kage	Date: Sept. 4, 2001 Citizen of: Japan	c/o Mitsubishi Shoji Plastics Corporation Gotanda Fuji Bldg., 27-2, ~~Nishigotanda 1-~~ chome, Tokyo 141-8535 Japan JPX
Name: Signature:	Date: Citizen of:	